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Development of a Computerized Training Requirements and Cost Evaluation System for the U.S. Marine Corps

Michael L. Donnell
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DECISIONS and DESIGNS, INC.

Prepared for
Defense Advanced Research Projects Agency
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by

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Defense Advanced Research Projects Agency
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This semi-annual report describes efforts to develop a resource management system for U.S. Marine Corps combat units and represents a step toward achieving that difficult goal. Specifically, this report delineates the conceptual framework and technical characteristics for the prototype benefit-cost model and accompanying computer software (called CTRACES) being developed for the Marine Corps Training Requirements and Cost Evaluation System (TRACES). CTRACES is designed to help battalion commanders develop a cost-effective strategy for remedial training. They will be able to identify how many points

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and what percentage of the Marine Corps Combat Readiness Evaluation System (MCCRES) deficit their battalion can be expected to make up for the best package of remedial training options at a specific dollar level of cost. In addition, battalion commanders will be able to evaluate the expected benefit and cost of particular training packages that they, or others, have proposed for consideration. The first field test of CTRACES is scheduled for late July 1980.

EXECUTIVE SUMMARY

This interim report describes the conceptual framework for and technical characteristics of the prototype benefit-cost model and accompanying computer software being developed for the Marine Corps Training Requirements and Cost Evaluation System (TRACES). The computerized system will be called CTRACES, for Computerized Training Requirements and Cost Evaluation System. Its purpose is to assist battalion commanders in developing cost-effective strategies for remedial training on the basis of their unit's Marine Corps Combat Readiness Evaluation System (MCCRES) score.

To accomplish this purpose, CTRACES will be capable of providing a battalion commander with the following information: (1) those areas in which the battalion exhibited performance deficits in the course of its MCCRES evaluation; (2) the different training options (or activities) that can be exercised to improve performance on individual tasks within each Mission Performance Standard (MPS); (3) the projected remedial training benefit of each option for tasks within each MPS; (4) the projected cost of each training option; (5) the projected improvement in combat readiness that can be expected for specific expenditures of training funds; and (6) the expected cost required to improve the battalion's combat readiness by a specific amount. The first field test of CTRACES is scheduled for July 1980.

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1.0 INTRODUCTION

Combat readiness is the primary goal of the Department of Defense (DoD). In the final analysis, virtually all of the resources of DoD are, or should be, dedicated to providing and maintaining combat-ready ground, sea, and air forces for the maintenance of U.S. national security. Implicit in that goal is the presumption that combat readiness is directly related to deterrence and to the likely effectiveness of armed forces, should they become engaged in actual combat. In this context, combat readiness is that organizational quality which reflects the level of preparedness for future combat.

The general level of combat readiness throughout the Armed Forces depends on the allocation of DoD resources. Changes in the allocation of defense resources undoubtedly cause corresponding changes in the level of combat readiness. That relationship suggests that the pursuit of combat readiness is a classic problem in resource management, one that is explained in the following paragraphs.

Ideally, as depicted in Figure 1-1, DoD resource managers would regularly sample and compare the current level of combat readiness with existing U.S. national security goals. The direction and extent of the deviation of the state of readiness from those goals would then stimulate the allocation of those particular DoD resources necessary to correct the discrepancy.

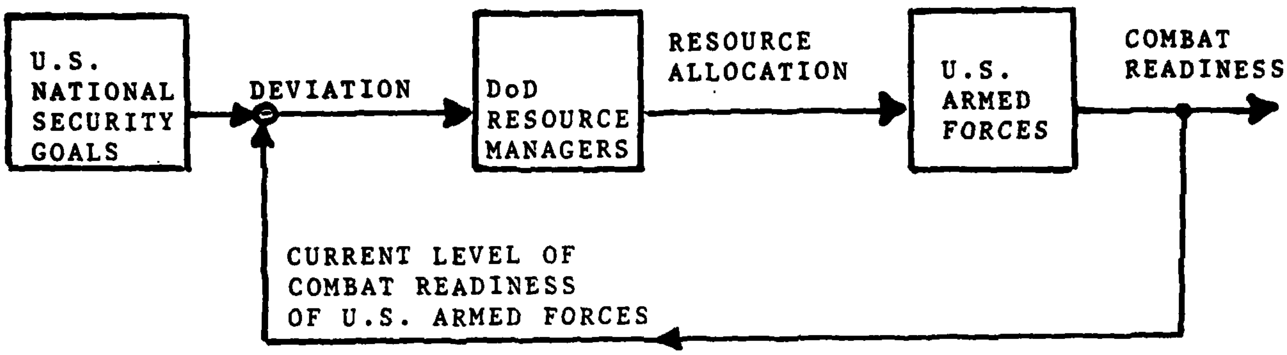


Figure 1-1

DoD MANAGEMENT OF COMBAT READINESS

The same feedback and control logic also applies to the management of force combat readiness by the appropriate headquarters command and to the management of unit combat readiness by force commanders (Figure 1-2).

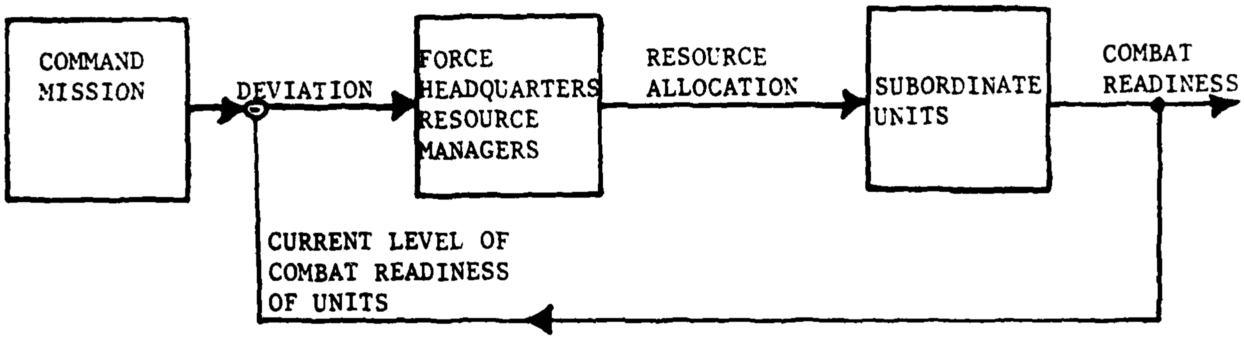


Figure 1-2

COMMAND MANAGEMENT OF COMBAT READINESS

This ideal framework simply reflects the principle that the combat readiness of a military unit is always the responsibility of the next superior command. At each command level, the commander influences the combat readiness of the subordinate units by managing and allocating the available resources, or by requesting the unavailable resources that

are necessary to correct any deviation in the required level of combat readiness consistent with the mission of the command.

The practical implementation of the ideal approach depicted in the above figures is difficult, however, because of the complex relationship between resource allocation and combat readiness. Unfortunately, it is also largely an ambiguous one, at present. There is no organizing framework within which DoD managers and military commanders can readily associate and compare the reported state of combat readiness with specified national security goals and command missions in order to determine discrepancies and initiate corrective action. As a result, DoD resources are too often allocated with little understanding of the impact the resources will have on the general state of combat readiness or, at the lower levels of command, on the combat readiness of specific military units.

Effective Dod resource management for combat readiness requires implementation of an organizational framework that integrates U.S. national security goals with the combat readiness of U.S. Armed Forces at the force, command, and unit levels, as illustrated in Figures 1-1 and 1-2. This is a difficult goal, and one that will take many years to complete. This interim report describes present efforts to develop a resource management system for U.S. Marine Corps (USMC) combat units and represents a step toward achieving that difficult goal.

Resource management systems have two broad components: an evaluation system and an allocation system. In 1976-1977 the Defense Advance Research Projects Agency (DARPA) agreed to fund an exploratory development effort that lead to a prototype evaluation methodology for the Marine Corps Combat Readiness Evaluation System (MCCRES). DARPA supported the

MCCRES development effort under the Advanced Decision Technology Program and arranged for the program's prime contractor, Decisions and Designs, Inc. (DDI) to work closely with Marine Corps personnel in developing a sound methodological approach. Combining the substantive expertise supplied by five Marine Corps officers assigned to the MCCRES project with proven decision analysis methodology, DDI constructed a prototype multi-attribute utility assessment (MAUA) model that permitted a rapid and systematic assessment of combat readiness. The model was successfully tested by the Marine Corps in August 1977, and MCCRES was adopted as the standard combat readiness assessment method for that Service. The implementing software for the assessment model, originally written by DDI for the IBM 5100 computer, was rewritten to permit implementation of the model on the IBM S/360 computer at Headquarters, USMC. MCCRES and its software model are now in routine use throughout the Marine Corps.

DARPA is presently funding DDI's efforts to construct a prototype benefit-cost model and accompanying computer software for the Marine Corps Training Requirements and Cost Evaluation System (TRACES). The computerized system will be called CTRACES, for Computerized Training Requirements and Cost Evaluation System. The cost-benefit model within CTRACES will use the combat readiness evaluation scores generated by the MAUA model within MCCRES to select and allocate training options that will provide battalions with the most training benefit for specific levels of cost. Thus, CTRACES will be the allocation component of the resource management system for USMC combat units. Field testing of the initial prototype system is scheduled for July 1980. This interim report describes the conceptual framework and technical characteristics proposed for the benefit-cost model within CTRACES.

2.0 TECHNICAL APPROACH

2.1 Conceptual Framework

The resource management system for USMC combat units will have two major components: (1) an explicit evaluation model that specifies how well the combat unit is performing each of its primary tasks, and (2) an explicit training model that specifies the most benefical remedial training activities for specific levels of cost. The components will be computerized so that they provide immediate post-evaluation information about the areas of weak performance and, subsequently, the most cost-beneficial training activities. Furthermore, to ensure its utilization, the computerized system will be straightforward and inexpensive to operate.

MCCRES is the evaluation component of the USMC system. MCCRES incorporates a multi-attribute utility assessment (MAUA) model that permits the systematic assessment of a USMC unit's combat readiness. In general, MAUA models are hierarchical in structure, starting with the specified top-level factor for which an overall evaluation score is desired. This factor is successively decomposed into subfactors in descending levels of the hierarchy such that each successive level is more specific than the one preceding. At the lowest level of the hierarchy are predictable or observable technical (or other) characteristics of the system under evaluation. These lowest level, highly specific characteristics are termed system elements.

Figure 2-1 presents a schematic of the MAUA model of MCCRES for USMC infantry units. The top-level factor is the overall combat readiness score. This factor is decomposed into separate categories of standards that specify the

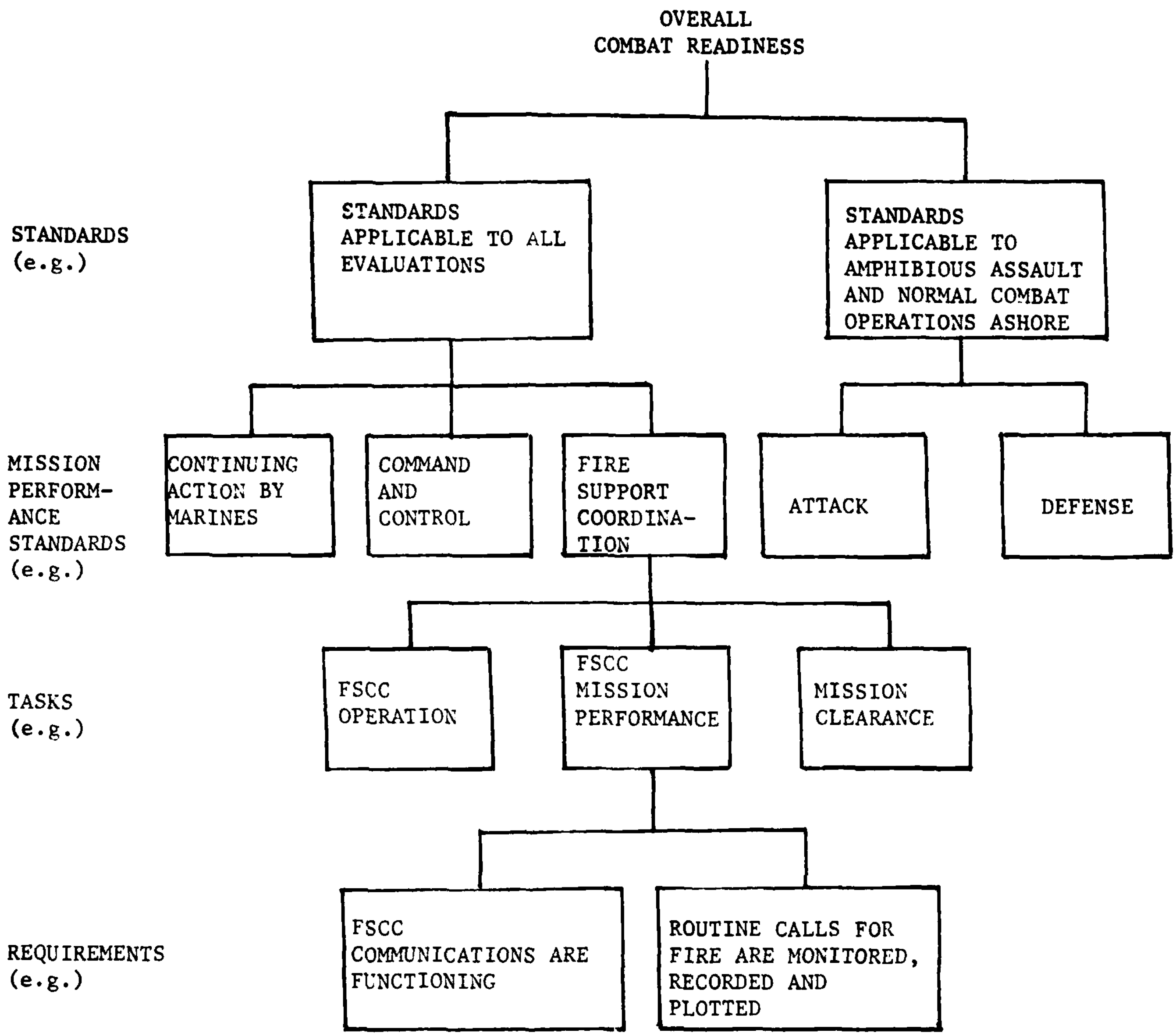


Figure 2-1

SCHEMATIC MAUA MODEL OF MCCRES FOR INFANTRY UNITS

appropriate mission performance standards (MPS) for the MCCRES evaluation. These standards are decomposed into specific tasks, which, in turn, are decomposed into the specific requirements that represent observable activities. Thus, different activities are integrated systematically to provide evaluation scores on individual performance areas and thereby yield an overall performance score.

The MAUA model is used, as follows, to provide an overall combat readiness score for an infantry unit. First, USMC evaluators rate whether the unit did or did not satisfy each of the requirements during the MCCRES evaluation. The unit's score on each task is computed by differentially weighting the ratings on the requirements comprising that task. Consequently, a unit that failed to satisfy important requirements on a task would get a low score on that task; if it failed the demand requirements, it could get a score of zero on that task. In a similar fashion, the unit's score on each MPS is computed by differentially weighting the tasks comprising that MPS; a low score on an MPS implies that the unit did poorly on important tasks within that MPS. The MPS's are differentially weighted to provide a score on the standards which, in turn, are differentially weighted to provide an overall combat readiness score for the unit. The more combat ready the unit, the higher the overall score produced by the MAUA model. Poor overall performance can be readily attributed to poor performance on specific performance standards, tasks, and requirements.

TRACES is the training component of the USMC system; as mentioned earlier, the computerized system presently being developed by DDI is called CTRACES. CTRACES will incorporate a general cost-benefit model that can be tailored to the needs of individual USMC battalions, as determined by their MCCRES evaluation. As a result, CTRACES will be

capable of telling a battalion commander (1) in what areas the battalion performed weakly during its MCCRES evaluation; (2) the different training options (or activities) that can be exercised to improve performance on individual tasks within each MPS; (3) the projected benefit of each option for tasks within each MPS; (4) the projected cost of each training option; (5) the relative improvement in combat readiness that can be expected for specific expenditures of training funds, and (6) the expected cost required to improve the battalion's combat readiness by a specific amount. Furthermore, CTRACES will be an interactive system that permits battalion commanders to ask questions about related issues they consider important in developing their actual package of training activities.

Figure 2-2 represents a schematic of the benefit model within CTRACES. Again, the relation between overall benefit and different training options is hierarchical to ensure the explicit integration of the evaluation and training components of the overall system. The top-level factor is the overall benefit produced by any proposed package of training options. Overall benefit is decomposed into the benefits obtained for each MPS, which, in turn, is decomposed into the benefits obtained for each of the tasks comprising the MPS. The greatest overall benefit is obtained by training activities that effectively exercise important tasks within important performance areas on which the USMC unit performed weakly. The most cost-beneficial training activities are those that most effectively exercise those tasks for the level of money allocated for training.

Figures 2-3 and 2-4 illustrate schematically the type of output that CTRACES will provide to battalion commanders. Figure 2-3, for example, identifies the MPSs, tasks, and requirements on which the battalion performed weakly during

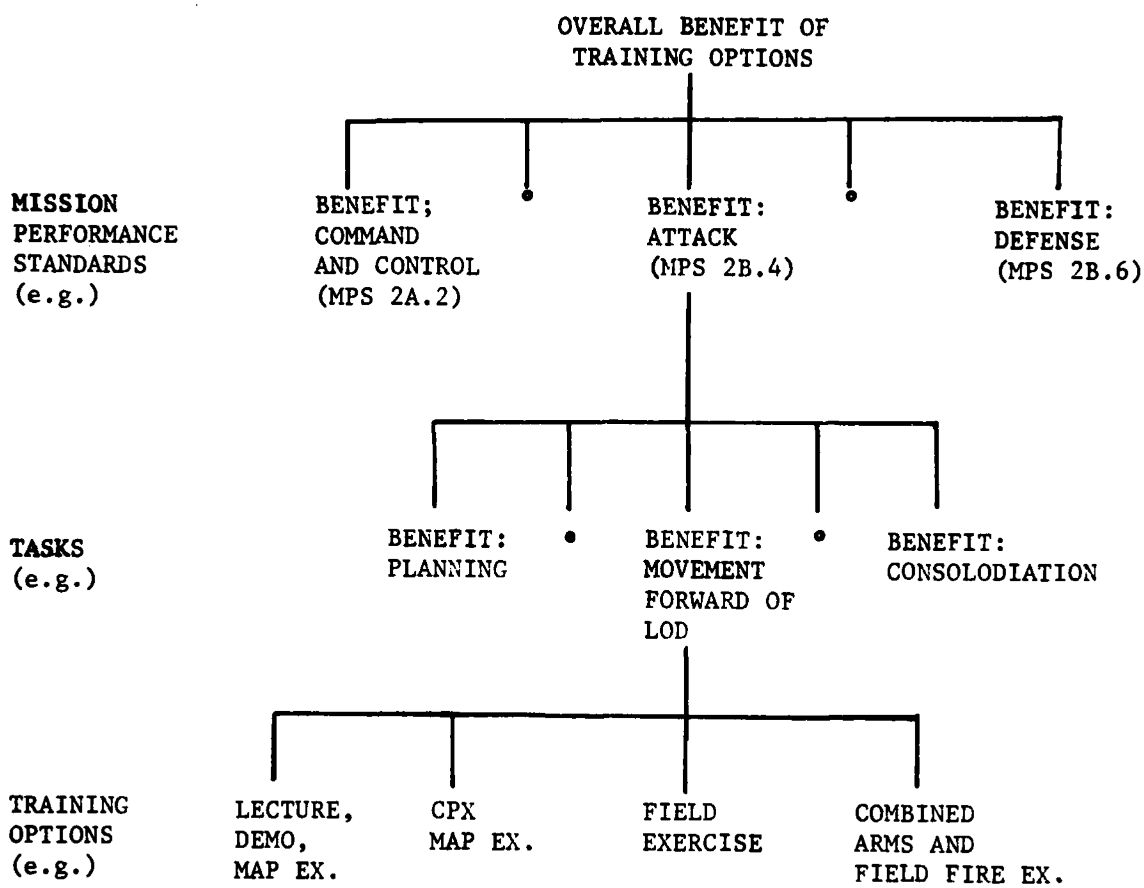


Figure 2-2

SCHEMATIC REPRESENTATION OF THE BENEFIT MODEL WITHIN CTRACES

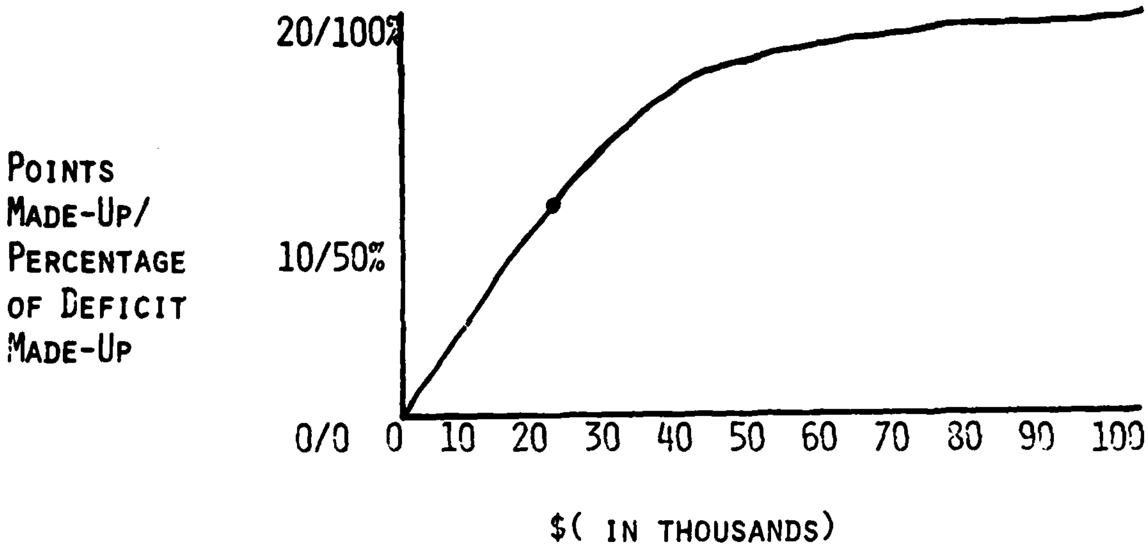
Mission Performance Standard #2	10 Points/50% of MCCRES deficit
Task #5	6 Points/60% of MPS deficit
Demand Requirements	None Failed
Other Requirements	Failed
Mission Performance Standards #1	3 Points/40% of MCCRES deficit
Task #11	8 Points/100% of MPS deficit
Demand Requirements	Failed
Other Requirements	None Failed
Mission Performance Standard #3	2 Points/10% of MPS deficit
Task #1	2 Points/100% of MPS deficit
Demand Requirements	None Failed
Other Requirements	Failed

Figure 2-3

REPORT INFORMING A BATTALION
COMMANDER OF THE MISSION PERFORMANCE STANDARDS,
TASKS, AND REQUIREMENTS ON WHICH HIS
BATTALION PERFORMED WEAKLY

its recently completed MCCRES evaluation. The MPS that accounted for the largest part of the MCCRES deficit from a perfect score of 100 is printed first. The other MPSs are printed in descending order based on the number of points and, thus, on the percentage of the MCCRES deficit for which they accounted; consequently, the MPS on which the battalion performed best is printed last. Within each MPS, the tasks are also listed in descending order based on the percentage of the deficit that they caused. CTRACES also identifies the requirements failed within each task. As a result, the battalion commander can obtain a quick overview of where the battalion's performance was weakest during the MCCRES evaluation and where remedial training should be directed.

On the basis of the MCCRES evaluation (for example, as illustrated in Figure 2-3), the battalion commander must develop a package of remedial training options, since different options are appropriate for different tasks. Any package of training options will have an expected dollar cost and expected benefit, in terms of the number of points or percentage of the deficit that can be made up. The benefit-cost curve identifies the package of remedial training options that makes up the largest deficit for each level of cost. An illustrative benefit-cost curve is presented in Figure 2-4. It indicates, for example, that for $20,000 the training package will make up 12 MCCRES points or, equivalently, 60% of the battalion's deficit on MCCRES. This package will include lectures for tasks #1 and #5 within MPS #2, a lecture for task #11 within MPS #1, and a two-day Command Post Exercise (CPX) for all appropriate tasks. None of the tasks will receive enhanced training beyond the minimum level required. Nor will task #1 within MPS #3 receive training, since it accounted for a very small part of the battalion's overall MCCRES deficit. Nevertheless, no other training option can make up more of the deficit for $20,000 on the basis of a cost-benefit analysis.



Cost? $20,000

Points Made-Up/PDMU: 12 Points/60%

Remedial Training Proposed for $20,000

- Lectures for MPS #2
  - o Tasks #1, 5
- Lectures for MPS #1
  - o Task #11
- 2 Day CPX for All Appropriate Tasks

Tasks Receiving Enhanced Training

- None

Figure 2-4

BENEFIT-COST CURVE FOR REMEDIAL TRAINING

It is important to point out that CTRACES cannot guarantee that the indicated number of points or percentage of deficit made up will actually be achieved in a second MCCRES evaluation. These values will have to be expected values. They will indicate that if an infantry battalion received a particular remedial training program immediately after its MCCRES evaluation and then took another MCCRES evaluation immediately after completing this program, then, on the average, the battalion would achieve these values on the exercised tasks. These values will be good estimates, particularly after subsequent field testing, but they cannot be guaranteed in every case. Similarly, CTRACES will not predict an overall MCCRES score because remedial training programs seldom train tasks upon which the battalion performed well during its MCCRES evaluation. Consequently, one cannot be sure that the battalion will perform these tasks well again. Presumably, the shorter the time interval between MCCRES evaluations, the higher the probability of repeated good performance.

In sum, CTRACES will be designed to help battalion commanders develop a cost-effective strategy for remedial training. They will be able to identify how many points and what percentage of the MCCRES deficit their battalion can be expected to make up for the best package of remedial training options at a specific $ level of cost. In addition, battalion commanders will be able to evaluate the expected benefit and cost of particular training packages by using CTRACES' interactive capabilities. CTRACES' technical characteristics are discussed in the next section of the report.

2.2 Technical Characteristics

CTRACES has many technical characteristics. They can be grouped into the following seven categories: (1) the

set of MCCRES MPSs, tasks, and requirements, (2) the set of remedial training options, (3) the matrix identifying those tasks within each MPS that are exercised by each option, (4) the expected benefit provided by each option for each appropriate task group within an MPS, (5) the expected cost of each option, (6) the computer algorithm for computing the benefit-cost curve, and (7) the benefit-cost curve and related output capabilities. Each group of technical characteristics is considered, in turn, below.

Before doing so, however, preliminary comments are in order. First, DDI analysts and USMC personnel have had primary responsibility for completing different technical characteristics of CTRACES. Division of responsibility was based on technical expertise. In particular, DDI analysts have had primary responsibility for CTRACES' conceptual and methodological framework, its benefit-cost algorithm, and its computer software. In contrast, USMC personnel have had primary responsibility for the substantive inputs necessary to complete the first five technical characteristics. Lieutenant Colonel P. R. Catalogne of Headquarters, USMC, has worked with DDI analysts throughout the entire project in order to (1) obtain the required substantive data from appropriate USMC personnel, and (2) ensure the substantive accuracy of the conceptual framework used in CTRACES.

Second, it should be kept in mind that many of these characteristics are still in a developmental stage, since the proposed version of CTRACES represents the initial prototype. The technical characteristics of CTRACES may well be modified on the basis of subsequent field testing and evaluation in actual settings. The first field test of CTRACES is scheduled for July 1980.

<u>MCCRES MPSs, tasks, and requirements</u> - The MPSs, tasks, and requirements included in CTRACES at a given time

are determined by the MCCRES evaluation. All infantry battalions, however, must exercise the following three MPSs: Continuing Action By Marines, Command and Control, and Fire Support Coordination. The battalion commander selects the other MPSs for the MCCRES evaluation.

The CTRACES prototype will include the weights for all requirements, tasks, and MPSs within MCCRES. It will not, however, include the evaluation scores because this would require the construction of computer software designed to link MCCRES and CTRACES, an effort which is not cost-effective at this time. Instead, the CTRACES prototype will require one to type in the MPSs used in the MCCRES evaluation, and the battalion's scores on the tasks comprising each MPS. Once entered into CTRACES, one will be able to print the infantry battalion's overall MCCRES score, the MPS and task scores, and the requirements failed. In addition, CTRACES will be able to calculate deficit measures based on the MCCRES evaluation. For example, the total number of points to be made up is 100 minus the overall MCCRES score; the number of points that can be made up on a particular task (i.e., the task deficit) is 100 minus the MCCRES score on the task; and the number of points in the overall deficit that can be made up on a particular task is the product of the task's cumulative weight in MCCRES and the task's deficit.

<u>Remedial training options</u> - There are four general options for the remedial training of infantry battalions: (1) a lecture (L) plus a demonstration and map exercise, (2) a command post exercise (CPX) plus a map exercise, (3) field exercises (FX), and (4) combined arms and field fire exercises (FFX+CA). The CPX and FX can be two, three, or four days long; the FFX+CA can be either three or four days long. The longer the duration of each option, the greater its expected benefit and cost. CTRACES will be able to assist

battalion commanders in selecting the most cost-effective length of time for each training option. It will, however, not assist the commander in deciding how the selected options will be implemented during actual training.

It is important to point out that battalion commanders must evaluate combinations of training options when selecting a remedial training program. For example, are lectures and a two-day CPX preferable to one three-day CPX for equivalent \$ cost? Is either preferable to a three-day FX, which provides greater benefit for greater cost? It is extremely difficult to answer such questions without analytical assistance because of the numerous possible combinations of training options. There are, for example, sixteen (2^4) possible combinations of the four training options if one does not consider the length of the option, because in each case the option is either given or not given. And if one does consider the duration of the training option, then there are 12,288 possible combinations of training options for the three required MPSs alone because there are eight possible lectures, four possible CPXs, four possible FXs, and three possible CA+FFXs (so, $2^8 \times 4 \times 4 \times 3 = 12{,}288$). A more detailed discussion of this point is found in the section describing the benefit-cost algorithm. For now, let it suffice to say that analytical assistance is required in order to efficiently evaluate the many possible training programs.

Option by task matrix - It is not feasible to exercise all tasks for all MPSs with each of the four general training options. Consequently, matrices have been developed to indicate the appropriateness of different training options for different tasks within each MPS. Figure 2-5 illustrates the option by task matrix for MPS 2B.4 ATTACK. This indicates, for example, that the Planning and Preparations tasks

MISSION PERFORMANCE STANDARD 2B.4 ATTACK

TASKS	OPTION I LECTURE DEMONSTRATION MAP EX	OPTION II CPX MAP EX	OPTION III FIELD EX	OPTION IV COMBINED ARMS & FIELD FIRE EXERCISES
PLANNING	X	X		
PREPARATIONS	X	X		
PRELIMINARY OPERATIONS			X	X
MOVEMENT FORWARD OF LOD—PRIOR TO CROSSING FCL		X	X	X
CROSS FCL CONDUCT ASSAULT		X	X	X
CONSOLIDATION	X	X	X	X
EMPLOYMENT OF RESERVE		X	X	X
RESPONSE TO COUNTERATTACK		X	X	X
C.P. DISPLACEMENT		X	X	X

Figure 2-5

OPTION BY TASK MATRIX INDICATING APPROPRIATENESS
OF DIFFERENT TRAINING OPTIONS
FOR DIFFERENT TASKS

can be exercised by a lecture and by a CPX, but not by an FX or by a CA+FFX. In contrast, the Preliminary operations task can be exercised by an FX or a CA+FFX, but not by a lecture or CPX.

In using the option by task matrices, CTRACES assumes that all appropriate tasks within an MPS are exercised for either a CPX, FX, or CA+FFX. Therefore, in terms of Figure 2-5, all tasks except Preliminary Operations are exercised for a CPX, and all tasks except Planning and Preparations are exercised for either an FX or a CA+FFX. Furthermore, CTRACES assumes that all appropriate tasks within all MPSs are exercised for either a CPX, FX, or CA+FFX. Again in terms of Figure 2-5, one CPX would exercise all eight tasks within MPS 2B.4 ATTACK; one FX would exercise seven tasks. This assumption represents how options are actually implemented in remedial training, for all appropriate tasks must be exercised to maintain the temporal sequence of a CPX, FX, or CA+FFX.

The lecture option differs from the other three, however, because often all appropriate tasks within an MPS cannot be covered by one lecture. Consequently, there will be a number of different lectures available to the battalion commander, but only one CPX, one FX, and one CA+FFX. This point is illustrated schematically in Figure 2-6.

Expected benefit - In CTRACES, the expected benefit (or value) of a training option is represented by the percentage of the deficit it should make up (PDMU) on an MPS. The expected benefit (or PDMU) of a training option for tasks within an MPS depends on (1) the battalion's MCCRES score on an MPS, (2) the overall effectiveness of the option for training on the MPS, and (3) the duration of the training option. This dependency is based on three assumptions. First, it was assumed that the better the battalion performed on an MPS, the more beneficial the option as a form

MPS #1	LECTURE	CPX	FX	FFX+CA
TASK 1	X	X		
TASK 2		X	X	X
TASK 3			X	X
MPS #2				
TASK 1	X	X		
TASK 2	X	X		
TASK 3			X	X
MPS #3				
TASK 1	X	X		
TASK 2	X	X	X	X
TASK 3	X	X	X	X

Figure 2-6

SCHEMATIC ILLUSTRATION OF
TASK GROUPS FOR DIFFERENT
TRAINING OPTIONS

of remedial training. Second, it was assumed that the more complete the training option, the greater the benefit; thus, it was assumed that a CPX provided more benefit than a lecture, that an FX provided more benefit than a CPX, and that a CA+FFX provided more benefit than an FX, in general. And third, it was assumed that the longer the training option, the greater the benefit.

Figure 2-7 shows the expected benefit (i.e., PDMU) of different training options for battalions with different MCCRES scores on MPS 2B.4 ATTACK. The figure is divided into four matrices, one for each training option. The first matrix, for example, indicates the percentage of the deficit that can be made up (PDMU) on the appropriate tasks within the MPS by a lecture, on the basis of the battalion's MCCRES score. The other three matrices indicate the PDMU on the appropriate tasks within the MPS by CPXs, FXs, and CA+FFXs of different durations on the basis of the battalion's MCCRES score.

It is assumed that the same percentage of the deficit is made up by a training option no matter what the score on an applicable task. This assumption rests on the argument that it becomes continually harder to make up a deficit, the smaller it becomes. Battalions with a low MCCRES score on a task will make up many points by exercising an effective option, while battalions with a high MCCRES score on the same task will make up only a few points with the same option. Nevertheless, both battalions will make up roughly the same percentage of the deficit on the task with the same option. Future field testing of CTRACES can, of course, subject this assumption to empirical investigation.

The PDMU values for CTRACES were provided by a group of more than twenty battalion commanders who presently, or formerly, conducted and participated in MCCRES evaluations

MCCRES	LECTURE
100-80	50
80-60	30
60-40	10
40	5

MCCRES SCORE ON MPS	CPX 2-Day	CPX 3-Day	CPX 4-Day
100-80	65	80	85
80-60	50	65	70
60-40	20	30	45
40	10	20	40

MCCRES SCORE ON MPS	Field X 2 Days	Field X 3 Days	Field X 4 Days
100-80	100	100+	100+
80-60	85	95	100
60-40	60	75	90
40	30	60	75

MCCRES SCORE ON MPS	FFX + CA	FFX + CA
100-80	100+	100+
80-60	100	100
60-40	80	95
40	60	80

Figure 2-7

PERCENTAGE - DEFICIT MADE UP (PDMU)
FOR MPS 2B.4: ATTACK

and helped develop CTRACES. Their judgments, as illustrated in Figure 2-7 incorporate the three assumptions identified above. For example, the decreasing PDMU values within any column (e.g., CPX: 2-day) indicate that an option is less effective, the poorer the battalion's MCCRES score on the MPS. The increasing PDMU values for different options (e.g., lecture, CPX, and FX) at the same MCCRES score level (e.g., 100-80) indicate that greater benefit is provided by more complete options. And finally, the increasing PDMU values for different durations of an option (e.g., 2, 3, and 4-day FXs) at the same MCCRES score level (e.g., 60-40) indicate that greater benefit is provided by a longer duration of training.

Further examination of Figure 2-7 indicates that a battalion with a specific MCCRES score on an MPS can obtain the same PDMU value with different options. For example, a battalion with a MCCRES score between 80 and 60 on MPS 2B.4 ATTACK can obtain a PDMU value of 100 by either a 4-day FX or a 3-day CA+FFX. No other training option, except a 4-day CA+FFX, will be that effective. On the other hand, no training option would provide a PDMU value of 100 if the battalion had a MCCRES score between 60 and 40 on this MPS.

In the case of a 4-day CA+FFX for the battalion with a MCCRES score between 80 and 60 on this MPS, the battalion would receive "enhanced training" (i.e., a PDMU value of 100+) because the extra day would permit the battalion to train on the tasks on which it performed well during its evaluation, as well as on the tasks on which it performed poorly. As a result, the battalion would be expected to (1) make up its complete deficit on the tasks requiring remedial training, plus (2) reduce the probability of subsequent poor performance on the tasks on which it performed well. Since the options in CTRACES are only for remedial training on those tasks requiring it, CTRACES will not give PDMU values

greater than 100. CTRACES will, however, indicate how many tasks receive enhanced training at different levels of cost to assist battalion commanders who favor training above the minimum required level.

Training costs - The $ cost of each training option can be subdivided into three general categories: the cost of the exercise itself, travel costs, and other related costs. All three categories, however, may not be particularly relevant for all four training options. For example, the cost of the lecture option is determined primarily by (1) the traveling costs for the Mobile Training Unit, and (2) the cost of the lecture demonstration, and map exercise itself. Regarding the latter, CTRACES will be capable of storing the incremental costs of up to twenty lectures. The cost of a CPX, in contrast, is essentially the cost of the 2, 3, or 4-day CPX; there are no travel costs. The cost of an FX of 2, 3, or 4-day duration, however, includes itself; (2) possible travel costs from the battalion's home base to either Ft. Erwin or 29 Palms in California (or some other location) if the FX is not performed at the battalion's home base; and (3) travel-related costs, such as "lodging" costs at other bases. In a similar fashion, the cost of a CA+FFX, which can be held only at 29 Palms, includes all three cost categories. If both an FX and a CA+FFX were being exercised in the same geographic area, reduced travel costs for this combined option would have to be computed accordingly.

The anticipated cost of each training option is being estimated by appropriate USMC personnel. To the extent possible, cost estimates for the July 1980 field test of CTRACES will be based on actual $ figures for training exercises in different locations. Cost figures will be improved

Benefit-cost computer algorithm - The computer algorithm in CTRACES for performing benefit-cost analysis is based on

DDI's resource allocation software, called "Design." Design's basic building block is a "variable"; a Design variable is one of the projects/programs competing for limited resources (e.g., $). Each of the competing variables is itself defined in terms of "levels" that describe increasingly costly options for it; one level must be selected by the decision maker for each variable. Finally, each level is described in terms of its cost and benefits relative to other levels. A fully defined collection of Design variables that compete for the same resource is called a Design "model."

Figure 2-8 illustrates schematically the variables and levels in CTRACES. In particular, the training options represent the variables in CTRACES because they represent the major program components competing for limited resources. Since individual lectures can be directed only to a small number of tasks, many lecture variables are listed in Figure 2-8. In fact, the number of lecture variables will be equal to the number of lectures actually required to train on all appropriate tasks. In contrast, only one CPX, FX, and CA+FFX is listed because each of these options exercises all appropriate tasks within the MPSs in the MCCRES evaluation.

The levels in CTRACES define all possible conditions for each of the variables. Consequently, each lecture variable is defined by two levels: not given and given. The CPX variable and the FX variable are defined by four levels, for in each case the option is either not selected or it is two, three, or four days in duration. Similarly, FFX+CA has three levels: not selected, three days' duration and four days' duration. Described thus, the levels on each variable represent binary switches that are either turned on or turned off. One, and only one, switch (i.e., level) can

Variables	Levels 1	2	3	4
Lecture 1	No	Yes		
Lecture 2	No	Yes		
⋮				
Lecture N	No	Yes		
CPX	No	2	3	4
FX	No	2	3	4
FXX+CA	No	3	4	

Figure 2-8

DESIGN MODEL VARIABLES AND LEVELS IN CTRACES

be turned on for each variable at a given time. The selected levels (or "on" switches) for all variables at that time represent one remedial training program. There are as many possible remedial training programs as there are different possible combinations of levels.

Each level of each variable has a cost and benefit associated with it. Anticipated costs will be calculated in a manner similar to that described in the last subsection. Cost values for FX and CA+FFX options will be stored in CTRACES in a manner that permits the battalion commander to identify the geographic location of the exercise prior to calculation of the benefit-cost curve.

The benefit value for all "no" levels will be zero. The benefit value for all the "yes/duration" levels represents the overall points made up (PMU) by that option. For example, the benefit value for the "yes" levels of a lecture (notationally represented as PMU_L) is determined by first calculating the PMU on each task for which that lecture provides remedial training and then summing up the PMU values on these tasks. One calculates the PMU by a lecture (L) on each task (t) by multiplying (1) the PDMU value for the lecture on a specific task (i.e., $PDMU_{t,L}$) by (2) the deficit score on the task ($DEFICIT_t$) by (3) the task's cumulative weight ($CUMWT_t$) in the MCCRES model. The overall points made up by the lecture (PMU_L) is represented arithmetically as follows:

$$PMU_L = \sum_{t=1}^{n} PMU_t = \sum_{t=1}^{n} PDMU_{t,L} \times DEFICIT_t \times CUMWT_t$$

where n equals the number of tasks exercised by lecture L.

The benefit values for the "duration" levels of a CPX, FX, and CA+FFX are represented arithmetically as follows:

$$PMU_k = \sum_{t=1}^{j} PMU_{m,t,k} = \sum_{m=1}^{j} PDMU_{m,t,k} \times DEFICIT_m \times CUMWT_{m,t}$$

where,

PMU_k represents the points made up by option-duration k (e.g., a 2 day CPX),

$PMU_{m,t,k}$ represents the points made up on task t within MPS m by option k,

$PDMU_{m,t,k}$ represents the percentage-deficit made up on task t within MPS by option k,

$DEFICIT_{m,t}$ represents the MCCRES deficit on task t within MPS m,

$CUMWT_{m,t}$ represents the cumulative weight in the MCCRES model on task t within MPS m, and

where there are a total of j MPSs, n tasks within a particular MPS, and k represents the particular option-duration combination. The reason for the difference in the two notations is that, in contrast to lectures, one CPX, FX, or CA+FFX exercises all appropriate tasks in all MPSs.

The overall percentage deficit made up by an option-level (i.e., $PDMU_k$) is the ratio of the overall points made up by that option-level (i.e., PMU_k) to the total possible number of points that could be made up. Arithmetically, this is expressed as follows:

$$PDMU_k = \frac{PMU_k}{\text{MCCRES DEFICIT}} = \frac{PMU_k}{\text{100-MCCRES SCORE}}$$

As was noted earlier, there are as many possible remedial training programs as there are different designs, i.e., possible combinations of levels. The overall benefit (i.e., PMU_o) of any remedial training program is the summed value of the PMU values of the individual option-levels that

compose it. Thus, the PMU_O will be considerably greater for a program composed of a CPX and FX than for a program composed of just two lectures. Unfortunately, the former program also will be considerably more expensive than the latter. The battalion commander must always consider this benefit-cost trade-off when selecting a remedial training program.

The benefit-cost algorithm in CTRACES is designed to help the battalion commander identify the training program (or "design") that provides the largest overall PMU for a specific level of cost. These programs are called "efficient" designs. In general, a design is called efficient if it has more benefit than other designs that cost as much or less. A design is not efficient if (1) there is another design that costs less but has the same or more benefit, or (2) there is another design that costs the same but has more benefit. In brief, an efficient design gives more benefit per resources expended than any other design with a similar benefit or expense; and an efficient design is more valuable than any other design with a similar benefit or expense. If the efficient designs for a model are known, and if the decision-making organization knows approximately how much resource it is willing to allocate in total, then the proper allocation among variables is usually easy to determine without further analysis.

A number of mathematical techniques can be used to identify a model's efficient designs. DDI's technique is built around benefit-cost ratios. A ratio is computed for each level or each variable, using the differences in benefit and cost between levels. The general idea is to measure every change between levels in terms of the benefit it provides per unit of resource. All the level changes in the model are ranked in order according to this benefit-per-unit-cost criterion. At one end of the order are changes

that give a great deal of benefit per unit of resource; at the other end are changes that give very little benefit per unit of resource. It can be shown that the designs corresponding to level changes that are selected in order of decreasing benefit-cost ratio are efficient designs. It is a simple matter for the computer (1) to determine the complete benefit-cost order or the level changes and (2) to use the order to identify the efficient designs implicit in it. A more technical description of the exact benefit-cost algorithm used in CTRACES will be provided at a later date.

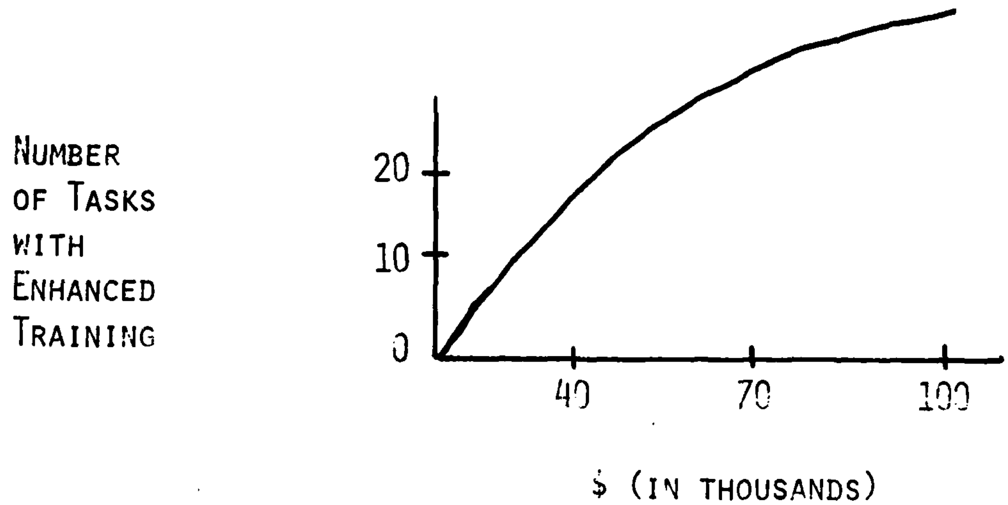
<u>Benefit-cost curves and related output capabilities</u> - The overall PMUs/PDMUs and costs for the efficient designs are printed as the benefit-cost curve in CTRACES. A hypothetical benefit-cost curve was illustrated in Figure 2-3. At every level of cost, one can identify the highest PMU value and thus, the percentage of the deficit made up. This permits battalion commanders to readily identify (1) how much it will cost to obtain a particular PMU/PDMU level, and conversely, (2) how high a PMU/PDMU level they can expect when faced with $ constraints for training. In addition, CTRACES will print out the description of the most efficient program at a specific cost level upon request, as illustrated in Figure 2-3.

It is important to re-emphasize that CTRACES cannot guarantee that the indicated PDMU values (and thus points made up) will actually be achieved in a second MCCRES evaluation. The PDMU values are expected values. They indicate that if an infantry battalion received a particular remedial training program immediately after its MCCRES evaluation and then took another MCCRES evaluation immediately after completing this program, then, on the average, the battalion would achieve these values on the exercised tasks. These values will be good estimates, particularly after subsequent field testing, but they cannot be guaranteed in every case. Similarly, <u>CTRACES does not predict an overall</u>

MCCRES score because remedial training programs seldom train tasks upon which the battalion performed well during its MCCRES evaluation. Consequently, one cannot be sure that the battalion will perform these tasks well again. Presumably, the shorter the time interval between MCCRES evaluations, the higher the probability of repeated good performance.

Battalion commanders might want (1) to train on tasks for which their battalion's performance was high and/or (2) to train beyond the minimum requirements on tasks for which performance was poor in order to increase the probability of a high overall score on a second MCCRES evaluation. CTRACES also prints out a benefit-cost curve for enhanced training to help commanders make this decision. Such a curve is illustrated schematically in Figure 2-9. It tells the battalion commander how many tasks are receiving training above their minimal requirements at each $ level of cost. This number is calculated on the basis of "100+" PDMU values as illustrated in Figure 2-7. It is assumed that all tasks within an MPS receiving a 100+ PDMU value for a training option will receive enhanced training. This information also will be printed for the commander, as illustrated in Figure 2-9.

CTRACES will have other output capabilities in addition to the printing of benefit-cost curves. For example, CTRACES will identify the overall PMU/PDMU values and cost for any proposed remedial training program. One need only specify the proposed levels on each of the variables, and CTRACES will print out the overall PMU/PDMU values and cost. Battalion commanders will be able to compare this proposed program with (1) the program that has a greater overall PMU value for the same cost and (2) with the program that has the same overall PMU value, but costs less money. In this way, battalion commanders can evaluate the basis for "efficient" remedial training programs.



COST? $40,000

POINTS MADE-UP/PDMU: 16 POINTS/30%

NUMBER OF TASKS RECEIVING ENHANCED TRAINING: 10

TASKS RECEIVING ENHANCED TRAINING

MPS #2

ALL TASKS

Figure 2-9

BENEFIT-COST CURVE FOR ENHANCED TRAINING

In addition to the output capabilities related to the benefit-cost curves, CTRACES will permit the battalion commander to request output indicating (1) in what areas the battalion performed weakly during the MCCRES evaluation, (2) the different training options that can be exercised to improve performance on individual tasks within each MPS, (3) the projected benefit (PDMU) of each option for the appropriate tasks within each MPS, and (4) the projected cost of each training option. In short, CTRACES will be an interactive system that permits battalion commanders to ask questions about related issues they consider important in developing their actual package of training activities.

3.0 SUMMARY

This interim report describes the conceptual framework and technical characteristics for the prototype benefit-cost model and accompanying computer software (called CTRACES) being developed for the Marine Corps Training Requirements and Cost Evaluation System (TRACES). CTRACES is designed to help battalion commanders develop a cost-effective strategy for remedial training. They will be able to identify how many points and what percentage of the MCCRES deficit their battalion can be expected to make up for the best package of remedial training options at a specific $ level of cost. In addition, battalion commanders will be able to evaluate the expected benefit and cost of particular training packages that they, or others, have proposed for consideration.

In general, CTRACES will provide battalion commanders with the following information: (1) those areas in which the battalion exhibited performance deficits in the course of its MCCRES evaluation, (2) the different training options (or activities) that can be exercised to improve performance on individual tasks within each Mission Performance Standard (MPS), (3) the projected remedial training benefit of each option for tasks within each MPS, (4) the projected cost of each training option, (5) the projected improvement in combat readiness that can be expected for specific expenditures of training funds, and (6) the expected cost required to improve the battalion's combat readiness by a specific amount.

The conceptual framework of the benefit model within CTRACES is a hierarchical, multi-attribute utility model. The top-level factor is the overall benefit produced by any proposed package of training options. Overall benefit is

decomposed into the benefits obtained for each MPS, which, in turn, is decomposed into the benefits obtained for each of the tasks comprising the MPS. The greatest overall benefit is obtained by training activities that effectively exercise important tasks within important performance areas on which the USMC unit performed weakly. The most cost-beneficial training activities are those that most effectively exercise those tasks for the level of money allocated for training.

CTRACES has many technical characteristics. They can be grouped into the following seven categories: (1) set of MCCRES MPSs, tasks, and requirements, (2) the set of remedial training options, (3) the matrix identifying those tasks within each MPS that are exercised by each option, (4) the expected benefit provided by each option for each appropriate task group within an MPS, (5) the expected cost of each option, (6) the computer algorithm for computing the benefit-cost curve, and (7) the benefit-cost curve and related output capabilities. Each group of technical characteristics was discussed, in turn, in this report.